Volumetric and Ultraacoustic Properties of Water Soluble Vitamins in Different Aqueous Media

Synopsis

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1. Introduction

Thermodynamic properties of solutions are found to be depending upon different types of molecular interactions in solutions. Ultrasonic technique reveals very weak intermolecular interactions due to its useful wavelength range. The studies of volumetric, acoustic and optical properties of solutions are attracting the attention of many workers which can be judged from the recent publication in the reputed journals.

The qualitative information about molecular interactions in solution can be collected from the measurement of ultrasonic velocity, density and related derived thermodynamic properties. The study of molecular interactions by the measurement of volumetric and acoustic properties of different solutions has got great importance in many fields of including medicinal chemistry, industrial processes, biochemistry etc.

Proteins, carbohydrates, fats, vitamins and minerals are playing an important role in performing normal functions of cells and organs, our body needs appropriate vitamins from food. Vitamins maintain mental health, immunity and aides in preventing certain chronic diseases and promote growth and development. Vitamins are essential nutrients that the human body needs in small amounts to tune biological processes properly. As vitamins are biologically important their biomedical properties are most commonly investigated. It is essential to study aqueous solution properties of vitamins in order to understand the mechanisms of their actions in detail.

The solute-solute, solute-solvent and solvent-solvent interaction can be studied by the measurement of density and ultrasonic velocity of solutions. This type of study helps us to understand the structure making and breaking properties of solutes and solution behaviors of solutes and reveal valuable information about solute–solvent interactions of proteins, carbohydrates, fats, vitamins, and electrolyte and non-electrolyte in different aqueous media. Thermodynamic properties of aqueous solutions play crucial role in understanding the nature of molecular interactions in binary liquid mixtures. Important parameters such as apparent molar volume, partial molar volumes, apparent molar compressibility, partial molar compressibility and related transfer properties are known to provide useful insight into solution structure and interactions.

The thermodynamic properties of different aqueous and non-aqueous systems at different temperatures and acoustical and volumetric properties of food components and vitamins in different aqueous media at different temperatures have been carried out by many workers.

2. Review of Literature and Development in the subject:

Several studies have been carried out on the thermo-physical properties of vitamins in recent years. Investigation of properties such as density, ultrasound velocity, refractive index over wide range of temperature, composition and in mixed solvents for many vitamins is still lacking in the literature.

Studies on thermodynamic and transport properties of aqueous solutions play crucial role in understanding the nature of molecular interactions in binary liquid mixtures. Despite their fundamental importance the volumetric values for aqueous solutions of vitamins are limited. It is necessary to study the thermodynamic properties of aqueous solution of vitamins in order to understand the mechanisms of their actions in detail. Volumetric and acoustic properties are important tools in studying the solution behaviors of solutes and reveal valuable information about solute-solute/solute–solvent interactions. There are very limited number of works in the literature for the volumetric and acoustic properties of vitamins and their interpretations in terms of vitamin–water and vitamin–water–co-solute interactions. The mechanism of action of vitamins is quite complex and this needs knowledge about the molecular interactions in fluids. The data for acoustic, volumetric and optical properties on most of vitamins are quite lack in aqueous media. Therefore we planned to carry out systematically the acoustic, volumetric and optical properties of vitamins in water at different temperatures.

Very dilute aqueous solutions of ascorbic acid have been used by Kaulgud et al. [1] in order to measure the densities and compressibility's of the solutions. Apparent molar volumes of ascorbic acid in water were determined by Apelblat and Manzurola. [2] Andrew W. Hakin et al. [3] reported the volumetric and thermo chemical properties of L-ascorbic acid in water at different temperature. Agnita Kundu et al. [4] reported apparent molar volumes of aqueous nicotinamide at different temperatures. M. L. Parmer et al. [5] reported the partial molar volume of organic acids in binary aqueous solutions of urea at different temperature. Volumetric studies have been carried out on nicotinic acid in water and in mixed aqueous solutions by various workers, Z. Orekhova,

E. Manzurola, M Ben-Ham, A. Apelblat [6]. Guler Ayranci et al. [7] have measured the density and ultrasonic velocity of ascorbic acid/thiamine hydrochloride in aqueous solution of HCl/NaCl at different temperatures. Irina V. Terekhova et al. [8] reported the volume studies the interactions between cyclodextrins and nicotinic acid in water. Hui-Ping Pan, Tong-Chun Bai et al. [9] reported density of a ternary solution of (Nicotinic Acid +Polyethanol + Water). Mahendra Nath Roy et al. [10] reported molecular interactions of nicotinamide in aqueous citric acid monohydrate solutions with reference to manifestation of partial molar volume and viscosity B-coefficient measurements. Sahin and Ayranci [11] have measured the density and speed of sound of ascorbic acid in aqueous solutions of polyethylene glycol at different temperatures. P. Sahaya Amutha et al. [12] reported apparent molal volumes and partial molar volumes of aqueous solutions of some biologically important compounds [glucose, sucrose, urea, citric acid, tartaric acid, ascorbic acid and oxalic acid] at different temperature. Tarlok S. Banipal, et al. [13] reported the volumetric studies on L-ascorbic acid, nicotinic acid, thiamine hydrochloride and pyridoxine hydrochloride in water at different temperatures and at atmospheric pressure. S.S. Dhondge et al. [14] reported the density, speed of sound and refractive index properties of aqueous solutions of vitamins B1.HCl and B6.HCl at different temperatures. Taghried A. Salman et al. [15] reported the thermodynamic properties of nicotinic acid in dilute HCl and in aqueous NaCl solutions at different temperature.

Abhijit Sarkar et al. [16] studied the thermodynamics of aqueous Nicotinic acid solutions in the presence of tetrabutylammonium hydrogen sulphate. Sudhakar S. Dhondge [17] reported the molecular interactions of ascorbic acid and sodium ascorbate with water at different temperatures. Mahendra Nath Roy et al. [18] explore the diverse interactions of nicotinic acid and ascorbic acid have been determined in aqueous mixtures of cysteine. Sudhakar S. Dhondge et al. [19] reported density and viscosity study of nicotinic acid and nicotinamide in dilute aqueous solutions at and around the temperature of the maximum density of water. Mahendra Nath Roy et. al. [20] explore the diverse interactions of some vitamins / nicotinic acid and ascorbic acid in aqueous mixtures of H_2O + [Epy] BF_4 systems by physicochemical contrivance. Ishani Banik, Mahendra Nath Roy [21] reported the structural effects of three carbohydrates in nicotinic acid/water mixed solvents. Vickramjeet Singh et al. [23] reported thermodynamic and ultrasonic properties of ascorbic acid in aqueous protic ionic liquid

solutions. C. Zhu et al. [23] studied the volumetric properties of amino acids in aqueous solutions of different vitamins. Abhijit Sarkar et al. [24] reported the effect of tetrabutylammonium hydrogen sulphate on the Solution thermodynamics of thiamine hydrochloride in aqueous solutions. Bijan Kumar Pandit et al. [25] reported volumetric studies of nicotinic acid in aqueous solutions of sodium malonate at different temperature. E. Yu. Tyunina,et al.

3. Objectives of Research / Proposed Hypothesis:

Objective of the present work as below:

1. To examine thermodynamic properties of important vitamins in solution in order to understand the overall structure of vitamins in solution and structural fittings in solution.
2. To understand the solute-solute and solute-solvent and solvent-solvent interactions and overall behavior of the water soluble vitamins molecule in different cosolute solution.
3. To generate the valuable data of measured properties such as ultrasound velocity, density, refractive index and derived their properties such as apparent molar volumes, partial molar volumes, specific and molar refractions, partial molar refractions etc. for the studied water soluble vitamins molecule in different cosolute solution.
4. To study the effect of added cosolutes on the studied thermodynamic properties of selected water soluble vitamins. To evaluate thermodynamic properties of vitamins which is depend upon concentration, temperature and relative composition of different cosolute solution.
5. To give comparative account of the thermodynamic behavior of different studied vitamins.

4. Methodology to be adopted:

Following experimental methods will be used in present study.

1. For measurements of the density of the various solutions, the standard pycnometer of fixed volumes will be used.
2. Ultrasonic velocity measurements of the vitamin solutions will be carried out using ultrasonic interferometer with temperature maintained water bath.

3. Refractive indices of the solutions will be carried out by using Abbes refractometer at constant temperature.

5. Importance of study/Society application:

(International status, national status & Significance of study):

The molecular interactions of vitamin with the different chemical compound such as salt, sugar, amino acids and biologically important drugs in aqueous solution is a significant factor for maintaining the structural behavior of vitamins. Consequently, the characterization of thermo-physical properties of vitamins solvation can give a hand in understanding the stability of vitamins. Interaction of vitamins with salt, sugar, amino acids and biologically important drugs in aqueous solution have been used widely in food, drug and pharmaceutical industries

- **International status:**

Since from the last three decades, the revolutionary developments in the physical chemistry in physicochemical parameters or properties in aqueous solution have done. The researcher gives the great contribution in the investigation of physicochemical, thermodynamic properties of various vitamins, biologically active important compounds throughout the world.

1. Z. Orekhova , E. Manzurola , M Ben-Ham , A. Apelblat. Department of Research and Development, Negev Academic College of Engineering and Department of Chemical Engineering, Ben Gurion University of the Negev, Beer Sheva, Israel. This team worked on apparent molar volumes and other volumetric properties of vitamins and bio-organic acids in aqueous solution.
2. Andrew W. Hakin, Susana.M. Mudrack And Colin L . Beswick. Department of Chemistry, University of Lethbridge,Canada. This group were investigated the volumetric properties of vitamins in water.
3. Guler Ayranci, Melike Sahin, Erol Ayranci. Chemistry Department, Akdeniz University, Antalya,Turkey. This team worked on the density and ultrasonic velocity of vitamins in aqueous solution.
4. Irina V. Terekhova*, Rosario De Lisi, G. Lazzara, Stefania Milioto and Nicola Muratore. *Institute of Solution Chemistry of Russian Academy of Sciences and Dipartimento di Chimica Fisica ‘F. Accascina’, Universit degli Studi di Palermo,

Viale delle Scienze, Parco D'Orleans II 90128 Palermo, Italy. This team worked on the density and interactions between cyclodextrins and nicotinic acid in aqueous media.

5. Hui-Ping Pan, Tong-Chun Bai, and Xuan-Dong Wang. College of Chemistry, Chemical Engineering and Materials Science, Soochow University,Suzhou, China. This team worked on density of a ternary solution of vitamins.
6. Taghried A. Salman, Khatab A. Abd. Department of Chemistry,University of Al-Nahrain, Baghdad, Iraq. This team worked on thermodynamic properties of vitamins. in aqueous media.
7. D. Ma, G. Wei, X. Jiang, C. Zhu. School of Chemistry and Chemical Engineering, Taiyuan University of Technology, Taiyuan, P. R. China, School of Chemical Engineering and Technology, Collaborative Innovation Center of Chemical Science and Engineering, State Key Laboratory of Chemical Engineering, Tianjin University, Tianjin, P. R. China. This team worked on volumetric studies of amino acids in vitamin aqueous solutions.
8. E. Yu. Tyunina,V. G. Badelin. G.A. Krestov Institute of Solution Chemistry, Russian Academy of Science, Akademicheskay str.1, Ivanovo, Russia. This team worked on volumetric properties and interaction of amino acids with vitamin in aqueous media.

Here few of the latest international researchers those have contributed for the physicochemical properties of vitamins, important biological compound in solution given below:

E. Carballo, R. Romani, C. A. Cerdeirina, C. A. Tovar, J. M. Satou, T. Nakamura, H. Hattori, T. Chiba, Krakowiak J, Koziel H, Grzybkowski W, R. Yendapally, R. E. Lee, Bioorg., H. Dai, A.Halder, B. K. Mandal, R. Sridevi, S. G. Naval_gund, C. Klofutar, J. Horvat, D. Rudan_Tasic, Acta Chim, Garcia, B., Alcalde, R. Aparicio, Leal J. M, Alvarez E., Sanjurjo B., Cancela A., Navaza, J. M., Sadeghi R., A. J. Parker, Gonzalez, C. A. Cerdeirina, Golabiazar R., Ziaii M., M. R. J. Deck, K. J. Bird. Etc.

- **National status:**

Apart from the international contribution, the Indian researchers have also made their contribution on thermo physical chemistry and physical chemistry.

1. M.V. Kaulgud, H.G. Dole, K.S.M. Rao. Department Of Chemistry Nagpur University Nagpur,India. This team worked on Apparent molal volume, apparent molal compressibility of vitamin in aqueous media.
2. Agnita Kundu and Nand Kishore. Department of Chemistry, Indian Institute of Technology Bombay, Powai. Mumbai-India. This team worked on Apparent molar volume of vitamin in aqueous media.
3. Tarlok S. Banipal, Harpreet Singh, Parampaul K. Banipal, Vickramjeet Singh. Department of Chemistry, Guru Nanak Dev University, Amritsar Punjab, India. This team worked on volumetric studies on vitamins in water.
4. M.L.Parmer, O.P. Sharma and M.K. Guleria. Department of Chemistry, Himachal Pradesh University, Summer Hill Station, Shimla, India. This team worked on partial molar volume of organic acids in binary aqueous solutions of urea.
5. Mahendra Nath Roy, Arijit Bhattacharjee, Palash Chakraborti, Ishani Banik. Department of Chemistry, North Bengal University, Darjeeling, India. This team worked on molecular interactions of vitamin in aqueous media of citric acid., interactions of vitamins in aqueous media of amino acids and structural effects of carbohydrates in aqueous media of vitamin.
6. Vickramjeet Singh, Gyanendra Sharma, Ramesh L. Gardas. Department of Chemistry, Indian Institute of Technology Madras, Chennai, India. This team worked on thermodynamic and ultrasonic properties of ascorbic acid in aqueous protic ionic liquid solutions.
7. Sudhakar S. Dhondge a, Prachi N. Dahasahasra b, Lalitmohan J. Paliwal c, Vijay.M. Tangde, Dinesh W. Deshmukh d. a P. G. Department of Chemistry, S. K. Porwal College, Kamptee, Dist., Nagpur India. b Priyadarshini College of Engineering, Hingna, Nagpur, India. c Department of Chemistry, R. T. M. Nagpur University, Nagpur, India. d G. H. Raisoni Academy of Engineering & Technology, Nagpur, India. This team worked on density, speed of sound and refractive index properties, molecular interactions of aqueous solutions of vitamins at different temperatures.
8. Harsh Kumar , Isha Behal. Department of Chemistry, Dr. B R Ambedkar National Institute of Technology, Jalandhar, Punjab, India. This team worked on thermodynamics, volumetric and acoustic properties of amino acids with thiamine hydrochloride in aqueous medium.

9. Ruby Rani, Ashwani Kumar, Rajinder K. Bamezai. Department of Chemistry, University of Jammu, Jammu , India. This team worked on effect of glucose/lactose on the solution thermodynamics of thiamine hydrochloride in aqueous solutions.
10. Ravi Sharma, Sonika and R.C.Thakur. Department of Chemistry, School of Chemical Engineering and Physical Sciences, Lovely Professional University, Phagwara, Punjab, India. This team worked on thermodynamic, acoustic behavior, partial molar volume of Nicotinic acid in binary aqueous mixtures of d-lactose.

In this area of research number of researchers is doing the work like:

V. J. Thakare, Balundgi R. H., Joshi S.S., Nikam P.S., Kharat S. J., Nayak J. N., A. Pal, N. Chauhan, M. Hasan, T. B. Pawar, A. B. Sawant, M. V. Rathnam, S. Mankumare, K. Jain, M.S.S. Kumar, S. D. Deosarkar, M. L. Narwade, Aralaguppi M. I., Aminabhavi T. M., Sastry N. V., Patel, M. C. Kumar, S., Kusakabe K., Chanda R., Mrityunjaya, I. A., A. B. Sinha, R. Dey, V. K. Dakua, M. Das, Awasthi RK etc.

These researchers focused on the various physicochemical, thermo-physical and thermodynamic properties of important drugs in aqueous as well as mixed solutions.

- **Significance of the study**

The study will have significance for the solution behaviour of studied vitamins and absorption of the vitamins. To understand the nature of interaction of water soluble vitamins with aqueous solution of different cosolute such as carbohydrates, salts, electrolyte, non electrolyte, biological and pharmaceutical important drug and amino acids, by means of the systematic measurements of densities, speeds of sound and refractive index. On the basis of this thermo-physical parameter we obtain the data about molecular interaction like vitamins – cosolute, vitamins - sugar, vitamins - salt, vitamins – amino acids and vitamins – drug, vitamins – electrolyte, vitamins – non electrolyte which have implications in the molecular interactions and structural behaviour of vitamins. Investigation on the thermodynamic properties to provide significance information that ultimately leads to better understanding of solution behavior of water soluble vitamins. The structure promoting and breaking tendency of added vitamins for solvent and cosolute the aqueous vitamins is analyze through thermodynamic properties.

6. Proposed work Plan/Formulation and structure of Study:

The proposed experimental work will be carried out as below:

Ist YEAR: Literature survey, instrument standardization, calibrations etc. and study of physicochemical properties such as density, ultrasonic velocity and refractive index and derived thermodynamic properties of some pure solvents, solvent mixtures, aqueous solutions of selected vitamins will be carried out.

IInd YEAR: Study of the physicochemical properties of selected water soluble vitamins in aqueous solution of three cosolutes (electrolyte, nonelectrolytes, drug, and amino acid) at different temperature will be carried out. In order to understand molecular interaction of vitamins in aqueous and aqueous cosolute solution at different temperature through thermodynamic and their derived properties. Calculation of derived properties and data fitting to standard equation will be carried out.

IIIrd YEAR: Fitting the experimental data to various laws, equations and scientific generalizations so as to get the computed properties for studied system. Results will be interpreted in terms of the molecular interactions. Communication of the obtained result to the journals etc.

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